Determinants of Adoption of Soil and Water Conservation Technologies in Coffee-Growing Areas of Ethiopia

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Abstract

Soil erosion is a threat to the economic development of Ethiopia as it affects the agricultural sector significantly. Even if several SWC practices were introduced and implemented to combat soil erosion, the adoption of these practices remains below the expectations. This study aimed to investigate the main factors that influence the adoption of physical SWC practices in coffee-growing areas of Ethiopia. The study used quantitative and qualitative primary data collected from subsistence farmers and other stakeholders from major coffee-growing areas of the country (Oromia and SNNP). Binary Logistic Regression (BLR) model was used to examine factors that affected the adoption of physical SWC practices. The study result showed that 49% and 44% of farmers used physical SWC practices on their land along Oromia and SNNP, respectively. Soil bund is a commonly used conservation practice in the study regions. Out of the adopters of physical SWC measures, 45% constructed soil bund which is higher at Oromia (53%) and low in the SNNP region (37%). The finding of the study also indicated the positive and significant effect of education, extension (access to extension services and participation on field days), and ownership of communication devices especially radio on the adoption of physical SWC practices. The study suggests policymakers and public authorities give due attention to problems affecting effective farmers-extension linkage. The farmers' training center system which is partially functioning currently should be strengthened to its full capacity. The positive effect of radio ownership on technology adoption also suggests the need for launching FMs channels to farmers which initially focuses on the provision of SWC practices information and knowledge.

Keywords

Extension, Land degradation, Logistic, Soil erosion, and SWC practices

1. Introduction

Ethiopian economy is heavily dependent on rain-fed agriculture which is dominated by smallholder farmers that are partially integrated into markets [1]. The outcome of the agricultural sector directly affects economic development, food security, and also poverty alleviation of the country [2, 3]. However, the role of this sector is hurt by land degradation such as soil erosion and nutrient depletion [4, 5, 6].

Studies showed that in Ethiopia, the soil loss rate ranges from 16 to 300 Mgha^{-1} yr^{-1}. The loss is highly dependent on the degree of slope gradient, land cover, soil type, and the nature of rainfall intensities [7]. Despite this, annual soil loss is diverse in space and time. For instance, [8] estimated annual soil loss of 93 Mgha^{-1} yr^{-1} for the entire Chemago watershed. Haile and Fetene [6] also estimated that about 97% of Kilie catchment has 0-10 Mgha^{-1} yr^{-1} erosion rate. In the same manner [9] pointed out that in Borena district of south Wello, the rate of soil loss was estimated to be 10 to 80

Mgha^{-1} yr^{-1}. About, 75% of the total area of the Gerado catchment, Northeastern Ethiopia, was found to have rates of soil losses which were >25 Mgha^{-1} yr^{-1}. Alongside, [10] estimated the highest soil loss at Medego watershed (35.4 Mgh^{-1} yr^{-1}) on the slope of 30%-50%.

Generally, from 1981 to 2008, the total land degraded in the country was estimated to be 297,000 Km^2 [11]. The mean rates of soil loss associated with croplands have been about 42 Mgha^{-1} yr^{-1} across the country [12, 13, 14] and recent estimates by [15] indicated rates of 20 Mgha^{-1} yr^{-1} on currently cultivated lands and 33 Mgha^{-1} yr^{-1} on formerly cultivated degraded lands.

Population pressure, inappropriate farming practices, and poor watershed management have contributed to a lion's share of the losses caused. Moreover, soil erosion hampers agricultural productivity through declining soil quality through excessive surface runoff, and also soil erosion causes the change in the physical properties of the soil [16].

Recognizing soil erosion as a major environmental and socio-economic problem, the Ethiopian government has designed and implemented a comprehensive sustainable land management project that focuses on a compromise between top-down and bottom-up approaches to watershed management activities [17, 18, 19, 20, 13, 14, 21, 11].

This watershed management approach has been implemented to minimize environmental degradation and enhance agricultural productivity which supports sustainable livelihoods security of the households.

The use of soil and water conservation (SWC) practices in association with crop production is determined by the combined effect of biophysical and socio-economic factors [22]. Consequently, the adoption of soil and water conservation practices in developing countries such as Ethiopia is very low and the expected change is far below the efforts done [23, 24].

Many introduced technologies have been rejected by farmers since they are simply inappropriate for the specific condition of small farm systems. Likewise, in Ethiopia, various factors were barriers to the full-scale implementation of SWC technologies. These include lack of awareness of soil erosion, institutional, socio-cultural, structural, environmental, and economic issues, lack of provision of adequate information on the technical details of innovation, inadequate extension services, and poor linkages with research teams, education, and poor transportation and communication networks, family size, land size, livestock holding, access to credit and training [25, 26, 27].

Therefore, this study focused on the main institutional, socio-economic, and bio-physical drivers for the adoption of SWC technologies in the coffee-based farming system of Ethiopia where conservation innovations are ignored and undermined. The farming system is characterized by undulating topography. However, poor adoption of soil and water conservation practices is the main feature of the area which has derived the farming system to high termite problems and acidic soil. The purpose of the study was to study the adoption of different soil and water conservation methods. Moreover, the study was anticipated to investigate determinant factors that affect physical soil and water conservation structures in the coffee-growing areas of Ethiopia.

2. Methodology

2.1 Study area description and the data

The study used quantitative and qualitative primary data collected from subsistence farmers and other stakeholders (experts, district, and zone officials) from coffee-growing regions of the country: Oromia and SNNP regions. Ilubabor, Jimma, West, and Kellem Wollega zones from Oromia, and Gedeo, Sidama, Kaffa, and Sheka zones were selected from SNNP regions.
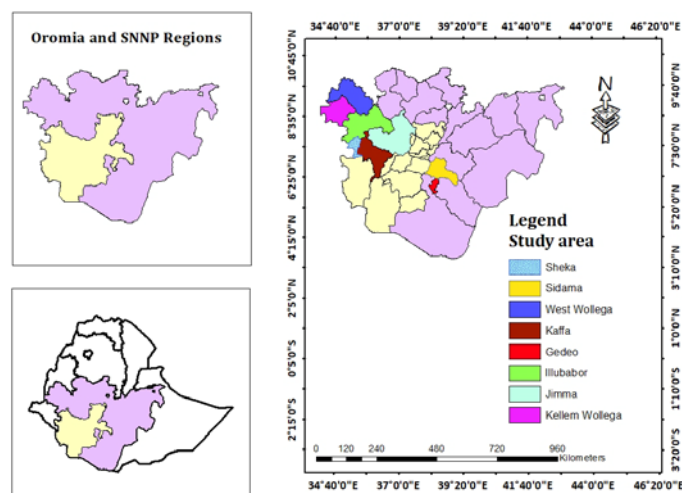

Figure 1. Map of the study area.

2.2 Sampling and data collection

A multistage sampling technique was employed to select the population for the study which involved both purposive and random sampling techniques. First, regions and zones were purposively selected based on the number of coffee growers, the area allocated for coffee, and the quantity of coffee produced. Accordingly, Oromia and SNNP regions were purposively chosen for the study since these regions alone accounted for 89% of coffee growers, 97% of the coffee area, and 99% of the coffee production of the country [28]. Secondly, districts and peasant associations were selected using a random sampling technique. Lastly, households were randomly chosen from the sampling frame of the coffee grower population at the peasant association level. Ultimately, a total of 953 sample households were selected for the study (584 from SNNP and 369 from Oromia Regions) (Table 1). Data were collected from the sampled households through a structured questionnaire administered to sampled farmers.

Table 1. Total sample size and sample distribution along study zones

Region	Zones	Total sample size	% of the total
	Gedeo	199	21
	Sidama	200	21
SNNP	Sheka	81	8
	Kaffa	104	11
	Sub-total	584	61
	Ilubabor	121	13
Oromia	Jimma	107	11
	West Wollega	105	11
	Kellem Wollega	36	4
	Sub-total	369	39
Grand Total		953	100

Source: computed from the data, 2019.

2.3 Data Analysis

Data were analyzed using descriptive statistics and econometric models. A logistic model was used to identify factors affecting the adoption of physical soil and water conservation structures. Hill and Kau [29] and Pindyck and Rubinfeld [30] reported for a farmer to adopt or not to adopt a specific technology, a reaction threshold of different factors affect. As such, at a certain value of stimulus below the threshold, no adoption is observed while at the critical threshold value, a reaction is stimulated. This is modeled as:

$$Y_I = \beta X_i^* + \mu_i \ \text{...} \ (1)$$

Where Yi is equal to one (1) when a choice is made to adopt and zero (0) otherwise and X* represents the combined effects of the independent variables (Xi) at the threshold level. The above binary choice model involves the estimation of the probability of adoption of a given technology (Y) as a function of independent variables (X). The probability of adoption and non-adoption is also modeled as:

$$prob(Y_i = 1) = F(\beta' X_i) \ \text{...} \ (2)$$

$$prob(Y_i = 0) = 1 - F(\beta' X_i) \ \text{...} \ (3)$$

Where Yi is the observed response for the ith observation of the response variable Y and Xi is a set of independent variables such as farm size among others, associated with the ith individual, which determines the probability of adoption, (P). The function, F may take the form of a normal, logistic, or probability function. The empirical model for the logit model estimation is specified as:

$$z_i = \log\left(\frac{p_i}{1-p_i}\right) = \alpha + \beta' X_i + \varepsilon_i \ \text{.......................................} \ (4)$$

Where Xi is the combined effect of X explanatory variables that promote or prevent farmers' decision to adopt modern agricultural production technologies and is the log-odds in favor of farm households' decision to adopt modern

agricultural technologies.

3. Result and Discussions

3.1 Characteristics of survey respondents

The study was considered different explanatory variables that could affect the adoption of physical soil and water conservation practices. According to the survey result, 90% of farmers were male-headed households. Age and family size were affecting the adoption of physical soil and water conservation practices. The mean age of the household head was 42 years old and the statistical result shows that there was no significant difference between the two regions in the age of household. The mean family size of the respondents along the region was 6 members and the mean number of years of education of the whole family and household head was 3.97 and 3.82 years, respectively. The mean distance from homestead to farm plots was 2.6 kms with a maximum of 11 kms, and 37% of farmers have access to credit services. The mean total land in the study area was 1.8 hectares, besides farmers also have on average 4.2 tropical livestock units (TLU). Coffee is the main cash crop in the study area. The study also included coffee adoption as an explanatory variable since the adoption of coffee could affect the adoption of soil and water conservation practices. The study result showed 60% of farmers have adopted improved coffee. Only 25% of farmers also participate in off-farm income-generating activities (Table 2).

Table 2. Description and summary statistics of explanatory variables

Variables	No. of Observation	Mean	SD	Min	Max
Region	953	0.612	0.487	0	1
Sex	953	0.902	0.297	0	1
Age	953	42.62	12.28	21	90
Family size	951	6.328	2.343	1	17
Household head education level (years)	953	4.811	3.489	0	16
Distance from homestead to farm plots in km	919	2.631	2.557	0	11
Radio ownership	953	0.54	0.498	0	1
Credit access	953	0.372	0.481	0	1
Extension service on soil and water management	953	0.852	0.355	0	1
Participation on field days	953	0.243	0.429	0	1
Participate in off-farm income-generating activities	953	0.251	0.424	0	1
Total land in hectares	928	1.756	1.788	0.01	12
Tropical Livestock Unit (TLU) in numbers	953	4.154	4.426	0	19
Improved coffee variety adoption	953	0.601	0.495	0	1

Source: computed from the data, 2019.

3.2 Respondents' access to extension services

In Ethiopia, the population is growing at an alarming rate and the demand for food is increasing. Feeding the growing population depends on securing and advancing the use of improved technology and approaches especially in Africa. Numerous farmers in such countries, though, continue to cultivate crops and raise livestock in the same ways that have been used in their communities for generations due to poor farmers-extension linkage and lack of access to inputs and markets. This survey showed that 86%, 78%, and 85% of respondents were provided extension services on crop production, livestock production, and natural resource management which is better despite the quality of the services. Alongside, farmers in the Oromia region have relatively better access to extension than the SNNP region counterparts (Figure 2).

Figure 3 depicted that, more than 20% of farmers have participated in demonstration or field days in both regions. There was an insignificant difference between the two regions in both training and field day participation.
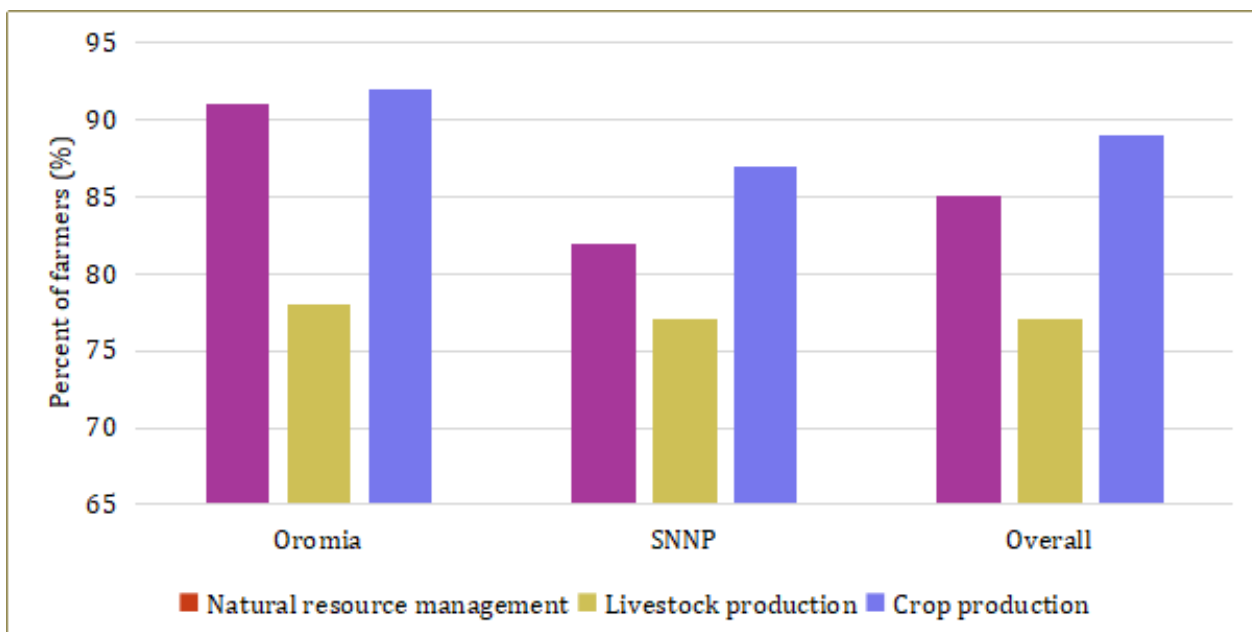
Figure 2. Farmers' access to extension services along the study regions in % (Source: computed from the data, 2019).
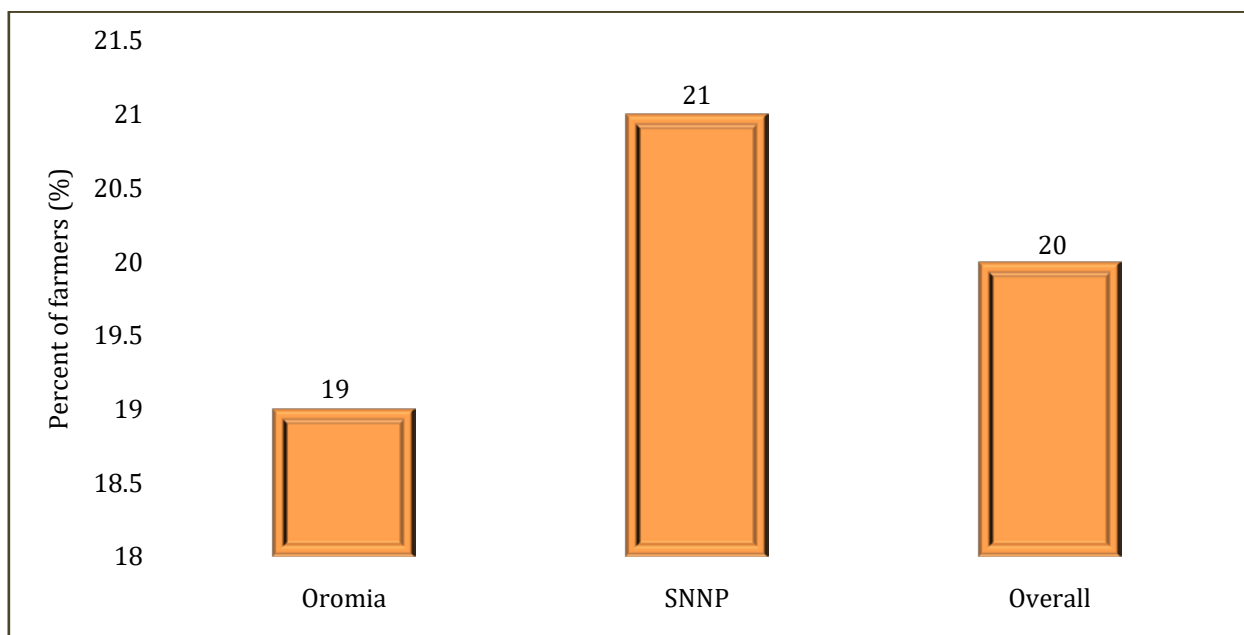

Figure 3. Farmers' participation in training and field days along study regions in % (Source: computed from the data, 2019).

3.3 Respondents' use of communication technologies

Communication in agriculture is crucial for producers to adopt the new agricultural technologies, sell the output, purchase the inputs, and mitigate the agricultural risks and disasters. It is the device used to transfer and/or receive information and knowledge.

The survey result assessed farmers' communication asset ownership along the study regions. The result exhibited that the majority of farmers owned mobile phones (63%) and functional radio (54%) in both Oromia and SNNP regions. Only a few farmers with access to electric power owned TV (11%). There was a significant difference between the Oromia and SNNP regions in the ownership of these communication technologies. A high number of farmers in SNNP owned both mobile phones and TV than farmers in the Oromia region (Table 3).

Table 3. Farmers asset ownership along the regions in %

Assets	Oromia	SNNP	Pooled	P-value
Mobile Phone	58	69	63	0.000[***]
Functional Radio	63	45	54	0.000[***]
Functional TV	8	13	11	0.035[**]

Notes. [***] $p<0.01$, [**] $p<0.05$, [*] $p<0.1$. Source: computed from the data, 2019.

3.4 Farmers adoption of minimum tillage

Minimum tillage involves minimizing the number of tillage operations by making only limited slots for placing the seed, either by using specialized machines (seeders) that open up small furrows in which the seed is placed or by manually using hoes or dipsticks to bore holes into which seeds are placed. Its purpose is to minimize soil disturbance since the rest of the field is left untilled [31, 32].

Farmers use minimum tillage to mitigate the effect of termites and soil acidity in the study areas. The use of minimum tillage was higher at SNNP than in the Oromia region with an overall mean of 36% (Figure 4). There was a significant difference between regions in the adoption of minimum tillage. Farmers in SNNP operate on small land size and plowing the land yearly could decline the soil fertility. Thus, they prefer minimum tillage to mitigate erosion which is the primary cause of soil fertility loss.
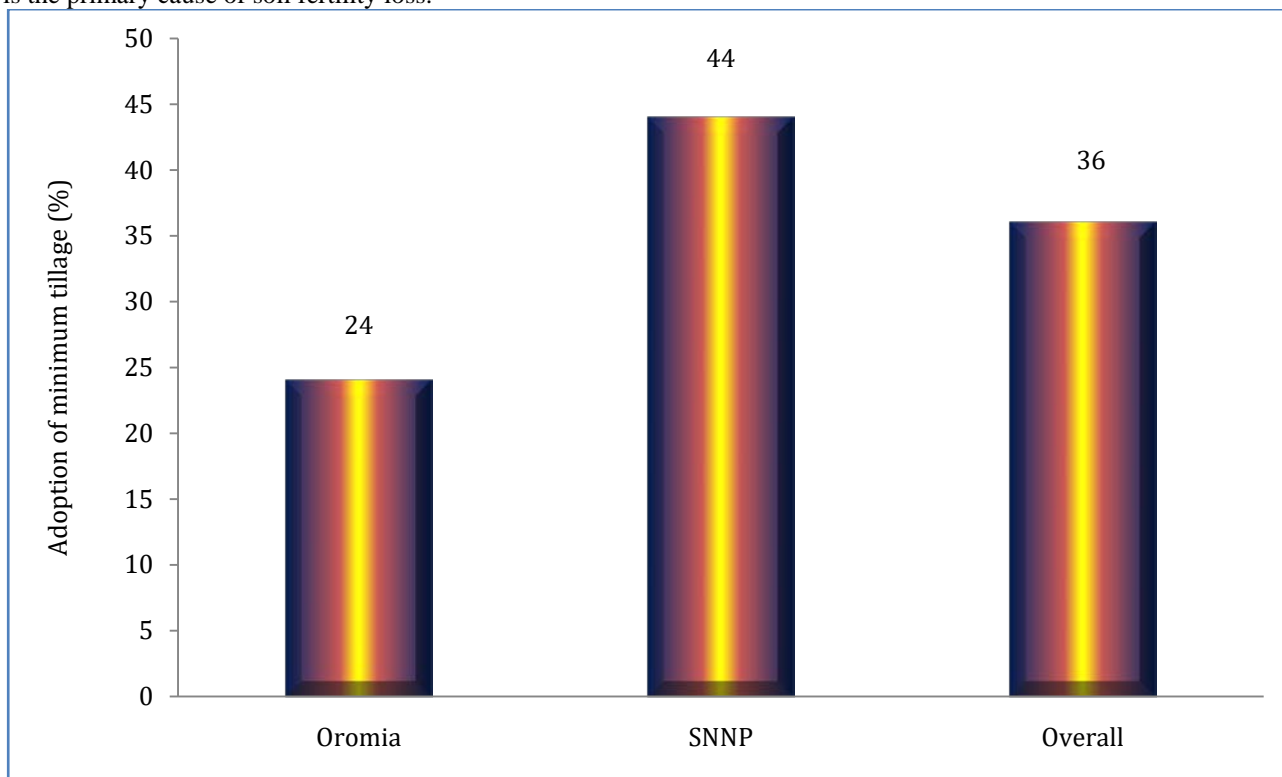

Figure 4. Adoption of minimum tillage in % (Source: computed from the data, 2019).

3.5 Farmers adoption of soil and water conservation structures

Land degradation in the form of soil erosion is the main challenge for sustainable development in the country. The degradation of land and soil erosion has adverse impacts on food security, soil nutrient depletion, water pollution, human health, and social and economic activities [33].

Due to the undulating topography of the coffee farming system and high intensity of soil acidity and termites as well as due to large space between coffee plants, farmers use different techniques of soil and water conservation practices to mitigate the problems and increase productivity per unit of land. These include fallowing, area closure, use of inorganic fertilizers, manure application, application of decomposed coffee husk, conservation tillage, intercropping, and cover cropping in coffee, the use of improved fodder, crop rotation, soil, and water management practices, and others. In this study, we have considered physical soil and water conservation practices. Addressing land degradation and soil erosion

through sustainable management of soil and land over physical soil and water conservation methods offers tremendous potential for climate change adaptation and mitigation as well as to enhance and sustain land productivity as well as to increase water productivity. Accordingly, this study has assessed the use of different physical soil and water conservation practices. The result showed that 49% of farmers in the Oromia region use the SWC structures which are higher as compared to the SNNP region (44%). Oromia region is characterized by undulling topography and high soil acidity and Termite is also the main production constraint in the region. SWC Conservation structures are recommended to combat the termites and reduce the soil acidity. This has derived the Oromia farmers to adopt SWC structures than farmers in the SNNP region. On average, 47% of respondents used soil and water conservation structures on their land along the study regions (Figure 5).
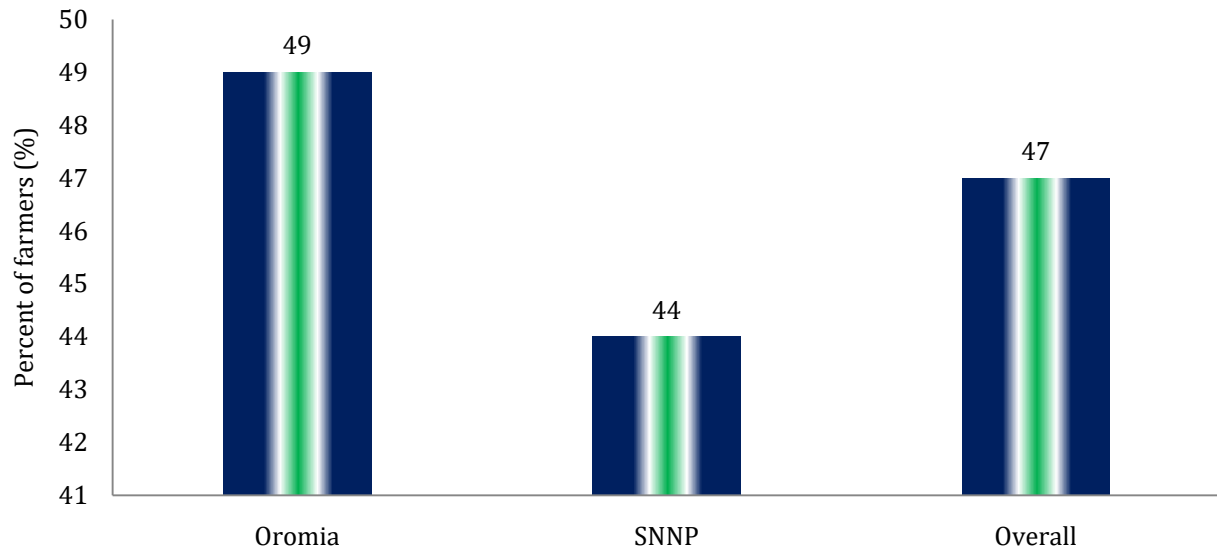

Figure 5. Adoption of physical soil and water conservation structures in % (Source: computed from the data, 2019).

Soil bund is a commonly used conservation practice in the study regions. Out of the adopters of physical soil and water conservation measures, 45% constructed soil bund which is higher at Oromia (53%) and low in the SNNP region (37%). The use of terracing and stone bunds also follows soil bund use among farmers of the study area (Figure 6).
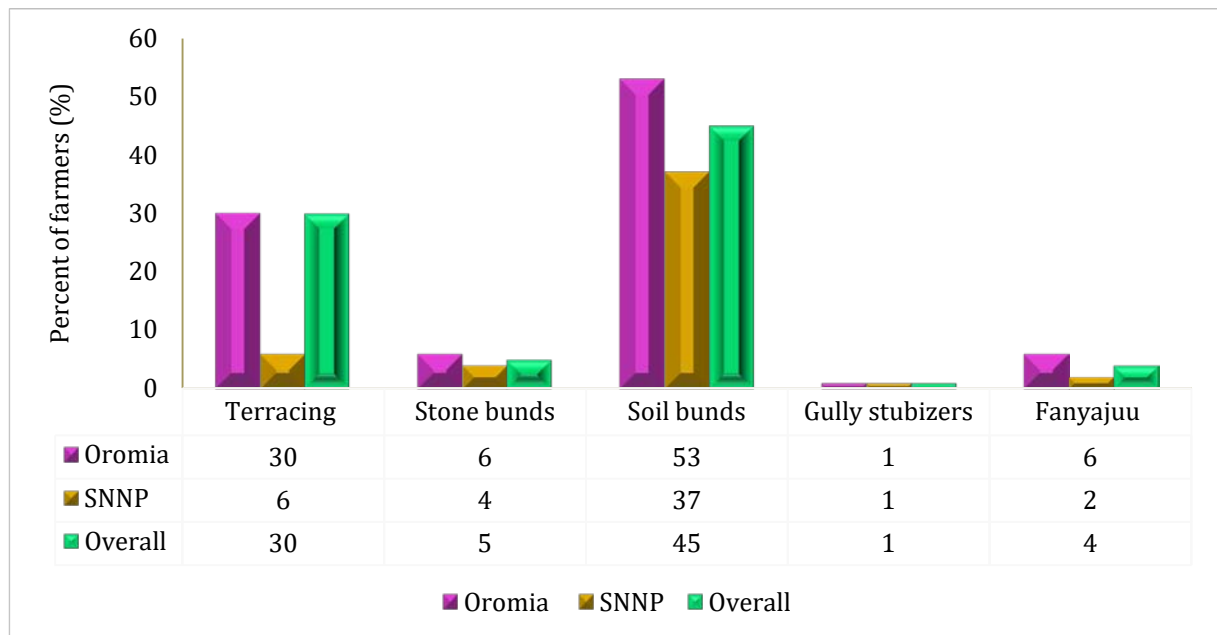

	Terracing	Stone bunds	Soil bunds	Gully stubizers	Fanyajuu
Oromia	30	6	53	1	6
SNNP	6	4	37	1	2
Overall	30	5	45	1	4

Figure 6. Type of physical soil and water conservation structures used in % (Source: computed from the data, 2019).

3.6 Factors affecting the adoption of physical soil and water conservation structures

The result of the logit model showed that the South nation nationality and people (SNNP) region is negatively related to the adoption of physical soil and water conservation structures which imply that the SNNP region is less adopter of the structures than the Oromia region. Oromia region farmers adopted the SWC structures highly and significantly to combat the problem of termite and soil acidity which is substantially high in the area due to high soil erosion. The result also supports the finding of descriptive statistics.

Source of information and knowledge such as ownership of radio, training, and access to extension services affect the adoption of physical soil and water conservation structures positively and significantly. The positive relationship between the adoption of physical soil and water conservation structures and extension service was also found by [34, 35, 36, 37, 38].

Better exposure to education increases farmers' better understanding of the benefits and constraints. Nonetheless, the result contrasts with [39].

Both oxen ownership and TLU positively and significantly affect the adoption of physical soil and water conservation measures. Since the investment in SWC structures is expensive (labor, time, and capital intensive), those farmers who have more TLU have the advantage to sell the livestock and use the money of the investment on conservation. The result is consistent with [25, 40, 41, 42, 43, 27] and contrasts with [7] and [44].

Table 4. Factors affecting adoption physical SWC practices

Variables	Coefficient	SE	t-value	P-value
Region (SNNP)	-0.66	0.183	-3.61	0.000***
Household head sex (Male)	0.209	0.258	0.81	0.418
Household head age	0.002	0.006	0.33	0.742
Household head education in number of years	0.032	0.034	0.94	0.348
Distance from homestead to farm plots	-0.004	0.013	-0.31	0.757
Participation of field days (Yes)	0.51	0.199	2.57	0.010**
Extension services (Yes)	1.55	0.238	6.52	0.000***
Radio ownership (Yes)	0.273	0.161	1.69	0.090*
Total land in hectares	-0.068	0.055	-1.23	0.22
TLU	0.085	0.024	3.46	0.001***
Oxen ownership (yes)	0.371	0.223	1.67	0.096*
Training on natural resource management (Yes)	0.443	0.17	2.6	0.009***
Credit services (Yes)	-0.007	0.159	-0.04	0.967
Participation on off-farm income generating activities (Yes)	-0.001	0.182	-0.01	0.995
Constant	0.686	0.667	1.03	0.303

Number of observation = 898

LR chi^2(14) = 113.64

Prob > chi^2 = 0.000

Pseudo R^2 = 0.100

Notes. *** p<0.01, ** p<0.05, * p<0.1. Source: computed from the data, 2019.

4. Conclusions and Policy intervention

Many soil and water conservation technologies have been popularized and disseminated in the country via research institutes and other development organizations. Despite research and development efforts, the low adoption of soil and water conservation technologies is the main challenge and driver to severe soil erosion and low agricultural productivity. This study was aimed to identify factors constraining the adoption of soil and water conservation practices. The result exhibited that 49% of farmers in the Oromia region use the SWC structures which are higher as compared to the SNNP

region (44%). The adoption rate of minimum tillage was also 36%.

The econometric result revealed that extension service, participation on field day, radio ownership, oxen ownership, TLU, and training on soil and water conservation practices are among the drivers to low adoption of SWC technologies in the study area. Thus, policymakers should pay due attention to the problems affecting effective farmers-extension linkage since the role of extension service is beyond expert assistance in the adoption of SWC practices. It also enables a flow of information and transfer of knowledge and scientific findings. The agricultural extension workers have an effective and important role in helping local farmers solve soil erosion problems. The farmers' training center system which is partially functioning currently should also operate to its full capacity. The positive effect of radio ownership on technology adoption also suggests launching FM channels to farmers which initially focuses on the provision of SWC information and knowledge.

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